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The effect of optical cooling of the SPM probe in the optomechanical resonator

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The optomechanical resonator is a connected system consisting of an optical resonator and a mechanical resonator. The simplest example of an optomechanical resonator is a Fabry-Perot resonator in which one mirror is stationary, and the second is attached to a spring and can oscillate. However, there are a huge number of other various designs of optomechanical resonators. In the last decade, studies of processes in optomechanical resonators have been actively carried out [1, 2]. Ongoing studies indicate the possibility of substantial optical cooling of microscopic mirrors in optomechanical resonators down to the ground state [3, 4]. This opens up a number of new research opportunities in the field of precision measurements of ultra-small forces [5], quantum computing [6], as well as in other areas. In this paper, we will study optomechanical resonators formed by the surface of an emitting semiconductor laser and the reflective surface of an SPM cantilever. The use of scanning probe microscopy techniques will allow a detailed study of the properties of such optomechanical resonators. The results of the work (optical cooling) can be used to significantly increase the sensitivity of the SPM during the detection of small forces.

The possibility of forming an optomechanical resonator “semiconductor laser - SPM probe” was experimentally investigated using single-mode ridge lasers with a well-known shape of an outgoing light beam. Optimal conditions were found (probe size and shape, probe coating, probe-surface distance) to achieve the best Q-factor of the optomechanical resonator.

There are determined and separated contributions from two mechanisms of optomechanical coupling: (i) – light pressure on the SPM probe, (ii) – heating the SPM probe. These two mechanisms can lead to a different sign of the oscillation frequency shift of the SPM probe in the optomechanical resonator, which can be experimentally verified. It was determined for which types of SPM probes one or another of the above mentioned mechanisms dominates.

The effect of optical cooling of an SPM probe in an optomechanical resonator was investigated by measuring the spectra of thermal vibrations of an SPM probe. Minimal achievable temperatures of SPM probe cooling were experimentally established.

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